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Relationship between indoor inhalant allergen concentrations, serum IgE, and allergic diseases: A cross-sectional study from the NHANES 2005–2006 program

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ABSTRACT

This research analyzed data from 5106 participants in the National Health and Nutrition Examination Survey 2005–2006 to explore the link between indoor allergen concentrations, serum IgE levels, and allergic diseases. The study found that 14.9% of participants reported having asthma, with significant differences noted in the concentrations of certain indoor allergens, specifically dust dog, mite, and cat allergens, between asthma and non-asthma groups. Furthermore, positivity rates for inhalant allergen-specific IgE and total IgE were higher in the asthma group. However, the correlations between most inhalant allergen IgE, including total IgE, and indoor allergen concentrations were very weak. These findings suggest that the relationship between indoor allergen concentrations and asthma incidence is complex, indicating a potential need for personalized allergen prevention strategies based on disease type and patient sensitization.

Keywords: Indoor allergen, Allergy, Asthma, Sensitization

TO THE EDITOR,

With the drastic changes in the human living environment, the global incidence of allergic diseases has shown a substantial increase.[1] Although genetics and epigenetics play an important role in the prevalence of allergic diseases,[2] the onset of allergic diseases cannot be separated from the influence of allergens. Exposure to allergens affects the occurrence and development of allergic diseases. Due to limited research, it is still unclear what the relationship is between the concentration of allergens in the living environment, serum allergen IgE, and various allergic diseases. There have been reports in the past that elevated indoor dust mite concentrations may be associated with allergic rhinitis and asthma.[3] However, while interventions against house dust mites may contribute to the control of allergic diseases, there is a lack of data support from large samples. Here, we analyzed and studied the data on indoor allergen concentration, serum allergen IgE, total IgE, and various allergic diseases using the NHANES (National Health and Nutrition Examination Survey) 2005–2006 in the United

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States to figure out the relationship between them and to provide new perspectives on the prevention and treatment of allergic diseases. The NHANES program collects data on the health and nutritional status of U.S. residents through random selection, which has the advantages of large sample size and strong representativeness.[4] In total, we obtained demographic information, allergic disease information, indoor dust allergen concentration values, serum-specific IgE, and total IgE values for 5106 participants (Table 1). There were 2594 (50.8%) females, 874 (17.1%) children aged 6–11 years, 1087 (21.3%) children aged 12–17 years, 1655 (32.4%) adults aged 18–44 years, and 1490 (29.2%) adults aged 45 years and older. There were 1231 (24.1%) in the low-income group, 2192 (42.9%) in the middle-income group, and 1683 (33.0%) in the high-income group. 1486 (29.1%) were diagnosed with allergic rhinitis, 409 (8.0%) with eczema, and 759 (14.9%) with asthma. There was no significant difference between gender and annual household income when comparing patients in the asthma group with those in the non-asthma group, but the age composition was younger for asthma patients. The prevalence of both allergic rhinitis and eczema was significantly higher in asthmatic participants than in non-asthmatic participants ($p < 0.001$). Concentrations of indoor dust dog allergens, dust mite fractions, and cat allergens (Can f 1, Der f 1, and Fel d 1) differed significantly between the 2 groups of participants, but not other inhalant allergens (Alt a 1, Asp, Bla g 1, Bla g 2, Der p 1, Mus m 1, and Rat n 1). Interestingly, however, the concentration of dust *Dermatophagoides farinae* 1 in the homes of participants in the asthma group was significantly lower than that of non-asthmatic participants, which may be related to the fact that asthmatic participants were more conscious about cleaning and mitigating mites from their home environments. As for inhalant allergens serum-specific IgE and total IgE, the positivity rate was higher in the asthma group than in the non-asthmatic participants, which is related to the close relationship between asthma and allergy.

We then examined the correlations between participants' indoor inhalant allergen concentrations and serum-specific IgE. As shown in Fig. 1, there were very weak correlations between the vast majority of inhalant allergen IgE, including total IgE, and concentrations of indoor allergens, with the maximum absolute value of all correlation coefficients being 0.03, and some of the correlations being statistically significant between them ($p < 0.05$). For example, the correlation coefficient between Der p IgE and dust Der p 1 was 0.03, $p < 0.05$, whereas the correlation coefficient between Der f IgE and dust Der f 1 was 0.02, $p > 0.05$. These results suggest that the relationship between human serum IgE and the concentration of allergens in the environment is complex, and that serum IgE may not be significantly positively correlated with the concentration of allergens in indoor dust. On the other hand, the correlation between the concentrations of indoor dust allergens was not strong, with the absolute maximum value of the correlation coefficient being 0.25, but the correlation was much more significant. For example, the correlation coefficient between dust Der p 1 and Der f 1 was 0.10, $p < 0.001$, suggesting a significantly weak positive correlation between them. In contrast, the correlation between serum IgE was much more pronounced, with a positive correlation between most of the serum inhalant allergen-specific IgE, and the correlation was statistically significant ($p < 0.05$). In particular, there was a significant positive correlation between serum total IgE and each specific IgE ($p < 0.001$). Similar to previous studies, the correlation coefficient between Der p IgE and Der f IgE was as high as 0.94, and there was a significant correlation ($p < 0.001$) due to the presence of cross reactivity between them.[5]

NHANES 2005–2006 has further questionnaires for asthma, including whether one still has asthma (current asthma), whether one has had an acute asthma attack in the past year, and whether one has had an emergency visit for asthma in the past year. We further analyzed these data. We found that there was no significant difference in the concentration of indoor allergens in patients between the 2 groups of whether or not they still had asthma. Whereas the prevalence of allergic rhinitis, eczema, and the prevalence of positivity for dog dander IgE, cockroach IgE, Aspergillus IgE, and rat IgE was significantly higher in the current asthma group, but there was no significant difference for other inhalant allergens (Table s1). For having an asthma attack in the past year, there were no significant differences

Variable	N = 5106	Asthma = No N = 4347 (85.1%)	Asthma = Yes N = 759 (14.9%)	P
Female Sex, n (%)	2594 (50.8%)	2205 (50.7%)	389 (51.3%)	0.81
Age, n (%) 6～11 12～17 18～44 45～	 874 (17.1%) 1087 (21.3%) 1655 (32.4%) 1490 (29.2%)	 736 (16.9%) 891 (20.5%) 1417 (32.6%) 1303 (30.0%)	 138 (18.2%) 196 (25.8%) 238 (31.4%) 187 (24.6%)	**<0.01**
Annual Income, n (%) Low Middle High	 1231 (24.1%) 2192 (42.9%) 1683 (33.0%)	 1030 (23.7%) 1886 (43.4%) 1431 (32.9%)	 201 (26.5%) 306 (40.3%) 252 (33.2%)	0.17
Allergic Rhinitis, n (%)	1486 (29.1%)	1113 (25.6%)	373 (49.1%)	**<0.001**
Eczema, n (%)	409 (8.0%)	291 (6.7%)	118 (15.5%)	**<0.001**
dust Alt a 1 (ng/mL)	0.14 (0.14, 0.14)	0.14 (0.14, 0.14)	0.14 (0.14, 0.14)	0.39
dust Asp (ng/mL)	5695.29 (2354.52, 8825.60)	5723.87 (2372.46, 8844.35)	5642.4 (2283.38, 8574.47)	0.75
dust Bla g 1 (U/mL)	0.01 (0.01, 0.04)	0.01 (0.01, 0.04)	0.01 (0.01, 0.04)	0.21
dust Bla g 2 (ng/mL)	6.93 (6.93, 10.83)	6.93 (6.93, 10.75)	6.93 (6.93, 11.52)	0.16
dust Can f 1 (ng/mL)	8.27 (1.13, 134.36)	7.59 (1.06, 117.96)	15.3 (2.04, 242.33)	**<0.001**
dust Der f 1 (ng/mL)	1.16 (0.42, 12.97)	1.23 (0.42, 14.09)	0.85 (0.42, 9.03)	**<0.001**
dust Der p 1 (ng/mL)	0.72 (0.42, 12.89)	0.76 (0.42, 13.73)	0.66 (0.42, 7.91)	0.10
dust Fel d 1 (ng/mL)	5.49 (1.10, 60.10)	5.04 (1.05, 47.88)	8.81 (1.68, 112.54)	**<0.001**
dust Mus m 1 (ng/mL)	0.85 (0.19, 3.44)	0.85 (0.19, 3.46)	0.84 (0.17, 3.36)	0.51
dust Rat n 1 (ng/mL)	0.14 (0.14, 0.22)	0.14 (0.14, 0.22)	0.14 (0.14, 0.22)	0.96
Positive Serum tIgE, n (%)	1752 (34.31%)	1382 (31.79%)	370 (48.75%)	**<0.001**
Positive Der f IgE, n (%)	1059 (20.74%)	780 (17.94%)	279 (36.76%)	**<0.001**
Positive Der p IgE, n (%)	1081 (21.17%)	795 (18.29%)	286 (37.68%)	**<0.001**
Positive Cat IgE, n (%)	629 (12.32%)	426 (9.80%)	203 (26.75%)	**<0.001**
Positive Dog IgE, n (%)	681 (13.34%)	454 (10.44%)	227 (29.91%)	**<0.001**
Positive Cockroach IgE, n (%)	705 (13.81%)	557 (12.81%)	148 (19.50%)	**<0.001**
Positive Alternaria IgE, n (%)	539 (10.56%)	360 (8.28%)	179 (23.58%)	**<0.001**
Positive Aspergillus IgE, n (%)	454 (8.89%)	305 (7.02%)	149 (19.63%)	**<0.001**

(continued)

Variable	N = 5106	Asthma = No N = 4347 (85.1%)	Asthma = Yes N = 759 (14.9%)	P
Positive Mouse IgE, n (%)	90 (1.76%)	48 (1.10%)	42 (5.53%)	**<0.001**
Positive Rat IgE, n (%)	82 (1.61%)	49 (1.13%)	33 (4.35%)	**<0.001**

Table 1. (Continued) Demographics, indoor dust allergen concentration, positive serum IgE between subjects with and without asthma
Note: Annual income means total annual household income. Annual income Low means annual household income was under $20000. Annual income Middle means annual household income was under $54999 but above $20000. Annual income High means annual household income was above $55000.Alt a 1, fungus Alternaria alternata 1. Asp, fungus Aspergillus fumigatus. Bla g 1, German cockroach Blattella germanica 1. Bla g 2, German cockroach Blattella germanica 2. Can f 1, Dog allergen Canis familiaris 1. Der f 1, Dust mite Dermatophagoides farinae 1. Der p 1, Dust mite Dermatophagoides pteronyssinus 1. Fel d 1, Cat allergen Felis domesticus 1. Mus m 1, Mouse urinary protein. Rat n 1, Rat urinary protein. Positive serum tIgE means the value of tIgE ≥60 kU/L. Positive specific allergen IgE means the value of sIgE ≥0.35 kU/L. Concentrations of dust allergens were expressed using median and interquartile range, and comparisons between groups were made using the rank-sum test. The positivity rate of serum IgE was expressed using number and percentage, and the chi-square test was practical for comparison between groups.

between the 2 groups in terms of gender, annual household income, and prevalence of eczema, but the prevalence of allergic rhinitis was significantly higher in the group with an asthma attack (Table s2). In addition, indoor Fel d 1concentrations were higher in participants with asthma attacks in the past year, but the concentrations of other allergens were not significantly different between the 2 groups. Dog dander IgE was significantly higher in the asthma attack group than in the no-asthma-attack group, but other inhalant allergen IgE and total IgE were not significantly different between the two groups. Finally, we performed a comparative analysis of emergency care visit for asthma in the past year (Table s3). The results showed that gender, age, annual household income, prevalence of allergic rhinitis, prevalence of eczema, indoor concentrations of various inhalant allergens, and positivity for the majority of inhalant allergens IgE did not differ significantly between the two groups of participants, and only Der f specific IgE positivity was higher in the group that had an emergency room visit.

In conclusion, our study found that the relationship between the concentration of indoor allergens and the presence of asthma may be complex. Concentrations of a few allergens such as indoor cat and dog allergens were higher in the group diagnosed with asthma, but dust mites were higher in the no-asthma group, whereas most of the other allergens did not differ significantly between the 2 groups. Moreover, the correlation between indoor allergen concentrations and serum-specific IgE levels was weak. There was also no significant correlation between current asthma status, acute exacerbations of asthma and emergency care visit for asthma in the past year, and concentrations of the vast majority of indoor allergens. However, total IgE and inhaled allergen serum IgE positivity were significantly higher in the group diagnosed with asthma, but there was no significant correlation between the majority of allergen IgE and current asthma status, acute exacerbations of asthma and emergency care visit for asthma in the past year. The current level of evidence for the effect of indoor allergen protection on asthma control is low to moderate.[6] In particular, some studies have found that indoor allergen control does not have the expected positive effect on asthma prevention and treatment.[7–9]

The birth cohort study by Carlsten C[10] et al, which included infants and young children at high risk of allergy, showed that early elevated dust mite exposure was associated with sensitization but not with asthma, and that indoor dog allergen exposure was not associated with sensitization but was associated with asthma development. The authors therefore concluded that the relationship between indoor allergen exposure and allergy and asthma is complex and similar to our results. However, the results of a nested case-control study conducted by S. Lin[11] et al showed that exposure to indoor allergens (including dust mites, cats, dogs, cockroaches, and mice) was strongly associated with sensitization and the development of asthma, but the number of cases in this study was small. Early studies have shown that mite allergens in indoor dust can only be dispersed into the air through disturbance and inhaled by the human, causing sensitization or allergic reactions.[12] This may also be one reason why there is not a clear correlation between the concentration of allergens in dust and sensitization.

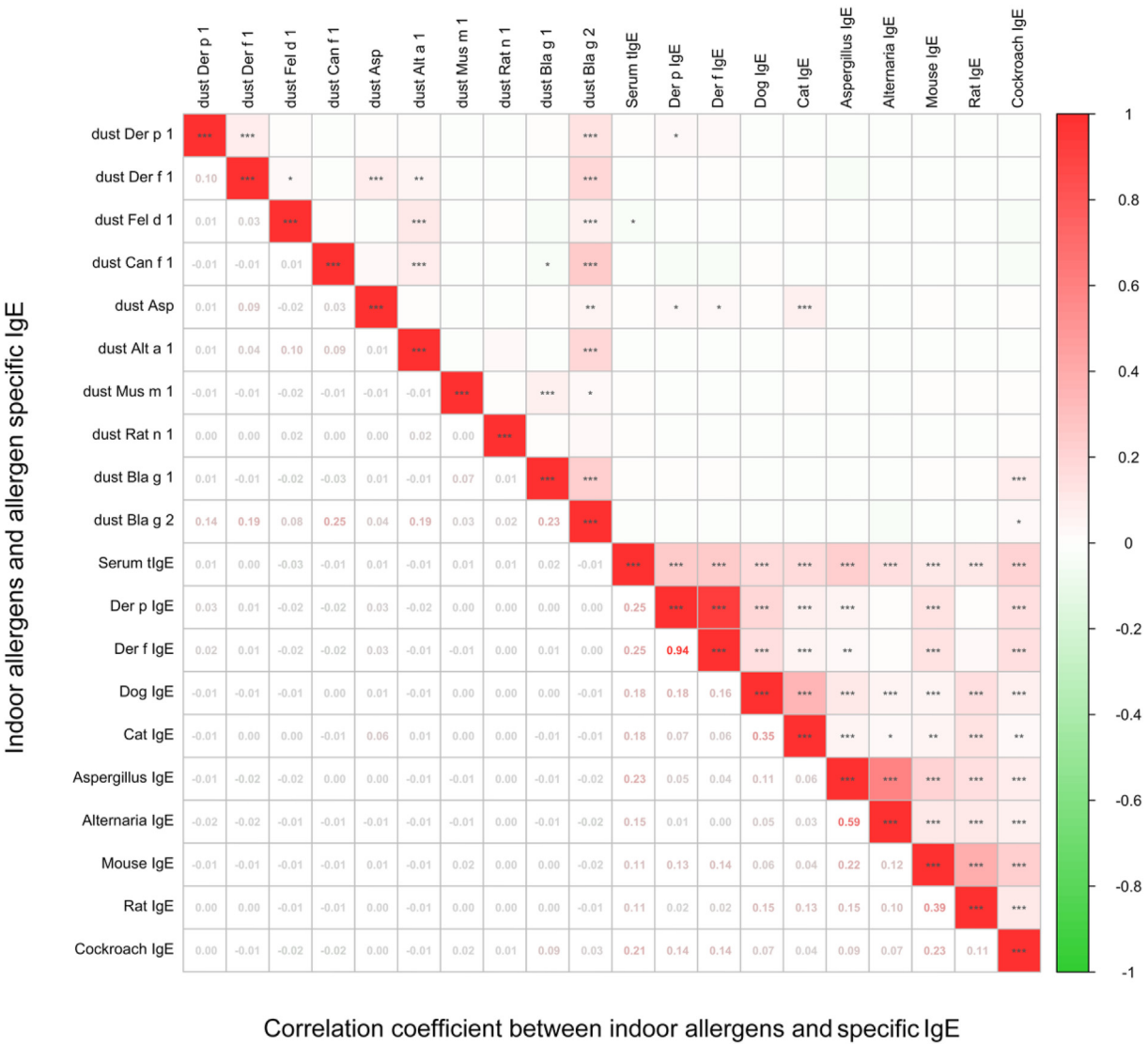

Fig. 1 Heatmap of the correlation between indoor allergen concentrations and serum IgE of the participants. The numbers in the lower left part of the image show the values of the correlation coefficient, a very strong correlation is defined as a correlation coefficient of 0.8 or above, a strong correlation as a correlation coefficient of 0.6–0.8, a moderate correlation as a correlation coefficient of 0.4–0.6, weak correlation as a correlation coefficient of 0.1–0.4, and very weak correlation as a correlation coefficient of <0.1, with the highest in red and the lowest in green. The upper right part shows the p-value of the correlation coefficient, *p < 0.05, **p < 0.01, ***p < 0.001. The solid red square in the middle represents the correlation between allergen IgE or indoor allergen itself.

Another study analyzed the relationship between indoor mouse allergen intervention and asthma outcomes using data from a randomized controlled clinical study,[13] which demonstrated that a decrease in indoor mouse allergen concentrations contributes to asthma control, especially in those asthmatics with high mouse allergen exposure at baseline. These studies and ours suggest that the relationship between indoor allergen burden and allergic disease is complex, and therefore, prevention of allergens may have to be targeted and individualized based on the type of disease and patient sensitization.

Abbreviations

NHANES, National Health and Nutrition Examination Survey. Alt a 1, Alternaria alternata 1. Asp, Aspergillus fumigatus. Bla g 1, Blattella germanica 1. Bla g 2, Blattella germanica 2. Can f 1, Canis familiaris 1. Der f 1, Dermatophagoides farinae 1. Der p 1, Dermatophagoides pteronyssinus 1. Fel d 1, Felis domesticus 1.

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Data availability statement
Data may be found on the NHANES website, accessed September 15, 2023 (http://www.cdc.gov/nhc/nhanes.htm).

Author contributions and consent for publication
Hui Gan conceived the study and was primarily responsible for study design, data analysis and supervised the project. Fei Ye and Gongkai He was involved in further developing the study design and statistical analysis and wrote the manuscript's first draft. All authors read and approved the final version of the manuscript and gave final consent for publication.

Ethical statement
Informed consent was obtained from all study participants. NHANES was approved by the institutional review board of the National Center for Health Statistics of the Center for Disease Control and Prevention (CDC). The Ethics Review Board (ERB) protocol number of NHANES 2005–2006 is #2005–06.

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Declaration of competing interest
The authors declare no conflict of interests.

Appendix A. Supplementary data
Supplementary data to this article can be found online at https://doi.org/10.1016/j.waojou.2023.100866.

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